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ABSTRACT

The majority of research investigating gender-related differences in problem-solving ability has focused on the product of word problem solving--the problem solution. This paper reports an investigation of potential gender-related effects on sixth-graders of an explicitly stated problem-solving plan. Two versions of the test were given: the formatted form, containing the seven steps of a problem-solving plan on each of the pages, with space for student work; and the unformatted form, containing only the word problems. Three classes of students (n=73) were administered the formatted test first, followed by the unformatted version. The remaining three classes of students (n=82) were administered the unformatted version first, followed by the formatted version. Females and males did equally well on both forms of a four-item problem-solving test. Students scored significantly higher on posttests that included the problem-solving plan. It was concluded that females benefited from free exploration of problem situations followed by an organized exploration. Contains 24 references. (MKR)

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The Gender Differential Effects of a Procedural Plan For Solving Mathematical Word Problems

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The Gender Differential Effects of a Procedural Plan For Solving Mathematical Word Problems

This research investigated potential gender-related effects of an explicitly stated problem solving plan for sixth graders. Females and males did equally well on both forms of the test. Students scored significantly higher (P= .023) on the posttests which included the problem solving plan. A repeated measures Analysis of Variance found a significant effect for time of testing (P=.001) and a significant interaction effect of time of testing, test sequence, and gender (P=.006). It was concluded that females benefited from free exploration of problem situations followed by an organized exploration.

Investigations of gender-related differences in mathematical ability have obtained a variety of results, however, several tendencies are apparent. Reviews and meta-analyses of research on gender-related differences in mathematics agree on two points. First, females tend to be superior in lower level, computational, algorithmic activities; whereas males tend to be superior in arithmetic reasoning, application and problem solving. Second, the differences in problem solving ability increase with the age of the subjects (Aiken, 1971; Fennema, 1974; Maccoby and Jacklin, 1974; Badger , 1981; Linn and Hyde, 1989; Hyde, Fennema and Lamon, 1990; Hyde & Fennema, 1990). Although researchers agree that age is a factor associated with gender-related differences in problem solving ability, studies disagree as to when males begin to outscore females on tests of problem solving ability. Some researchers have found differences at the upper elementary level (Maccoby and Jacklin, 1974; Badger, 1981), while others suggest that differences are not apparent until High School (Linn and Hyde, 1989; Hyde, Fennema and Lamon, 1990; Hyde & Fennema, 1990) .

Individual studies offer similar conclusions. Marshall (1984) compared the scores of 286,767 sixth graders on computational items and also on story problem items from the California Assessment Program's *Survey of Basic Skills*. The females tended to score higher than the males on computation items while the males tended to score higher than the females on word problem items. Armstrong (1981) reported results of the *Women in Mathematics Project*, a national survey conducted by the Education Commission of the States in 1978. Based on items from standardized tests, females age 13 (approximately eighth grade) scored significantly higher than males on both computational skills and also on spatial abilities. Males significantly outperformed females in solving one and two-step routine story problems.

Moore and Smith (1987) analyzed data for gender-related differences collected in the *National Longitudinal Study of Youth Labor Force Behavior*. Data were obtained from both the *Mathematics Knowledge* and the *Arithmetic Reasoning* subtests of the *Armed Services Vocational Aptitude Battery*. No significant differences were found on scores on *Mathematics Knowledge*, but an ANOVA did indicate significant main effects for gender in ninth grade and beyond for scores on the *Arithmetic Reasoning Subtest*. The *Arithmetic Reasoning Subtest* was comprised of multiple choice arithmetic word problems. The authors concluded that ability to solve arithmetic word problems increased with age for both genders, and also that the magnitude of the gender-related difference in word problem solving ability increased with educational level.

Male superiority in word problem solving is not only apparent in general mathematics tasks, but also in algebraic tasks. Phillips, Uprichard and Blair (1983), measured the ability of 320 high school algebra students to solve algebraic word problems. On a measure of eight types of routine algebraic word problems commonly found in algebra textbooks the males overall averaged 5.16 points, of a possible 72, higher than the females.

Swafford (1980) also tested high school algebra students using routine consumer word problems. These consumer problems were described as word problems dealing with buying, selling, interest rates, and other topics concerning the uses of money. Boys did better than girls at the beginning of the course in algebra and boys improved even more than the girls by the end of the course in algebra. These results are consistent with the research which indicates that gender-related differences exist in word problem solving ability and that these differences increase in magnitude over time. They also indicate that gender-related difference in word problem solving ability in favor of males first appears in the sixth grade (Marshall 1984). The superiority of males in word problem solving ability persists through the middle grades (Armstrong, 1981) and into high school and college (Moore & Smith, 1987; Phillips, et. al., 1983).

The majority of research investigating gender-related differences in problem solving ability has focused on the *product* of word problem solving, the problem solution. Focusing on the process of problem solving, Zambo (1994) found that females were more capable than males of using a procedural problem solving plan composed of selected strategies. The author hypothesized that the difference favoring males on tests of problem solving ability could be mediated through the use of an explicitly stated problem solving plan.

Problem Solving as a Process

Although no single accepted description of the problem solving process exists and is not likely to exist. Elementary school teachers approach word problem solving in the manner that is suggested by the prescriptive plans presented in mathematics textbooks. These plans are designed for use with the routine word problems, problems which can be solved through the direct application of algorithms, found in the same textbooks. Although routine word problems are only one component of problem solving as

envisioned by the National Council of Teachers of Mathematics (1989), they comprise the majority of textbook word problems (Stigler, Fuson, Ham & Kim, 1986). The modifier "routine" should not be confused with "easy". Many students experience frustration and failure in solving even "routine" problems.

The step by step plans vary between texts but contain commonly recommended steps and strategies. This similarity of plans is no doubt due to the influence of Polya's (1945) seminal work on problem solving. Textbook authors have used Polya's four phases of problem solving, insufficient in themselves as a prescription, as a framework for building step by step plans workable for middle grade students.

Textbook plans offer steps to follow when solving a word problem, for example. Read the problem, Plan, Find the answer, Check the answer. In addition to the general plan, the textbooks supply students with strategies for completing each step in the plan. These attempts to operationalize the rather abstract plan for elementary aged students include identifying both the given facts and the question when reading the problem, drawing a diagram or model choosing an operation, writing an equation, solving the equation, estimating, and checking that the answer makes sense.

Mathematics educators have attempted to present similar plans for word problem solving. One such model (Phillips, Uprichard & Johnson, 1974; Soriano & Phillips, 1982; Uprichard et al., 1984) included eleven steps intended to make Polya's plan workable for children. Steps for understanding the problem were; read the problem, paraphrase the problem, circle the facts, list the known facts, and list the unknown facts. Steps for devising a plan were; diagram the problem, estimate an answer, choose the operations, and write an equation. Following the plan involved solving the equation and writing the answer. Looking back was operationalized as comparing the answer to the estimate and checking the computations.

Although prescriptive plans might be viewed as a simplistic approach to problem solving, the general nature of their components is congruent with findings about the methods which students use to solve problems. Researchers have observed students solving problems and identified the strategies they used. The findings suggest that students use the problem solving strategies found in textbooks. Webb (1979), studying college algebra students, found that after reading the problem (a necessary first step in all plans) students used strategies such as; drawing a diagram (the most commonly used strategy), writing an equation, using an algorithm, and verifying the solution. Sherrill (1983) conducted a similar study with seventh grade mathematics students. Sherrill found strategies used by the subjects included; reading the problem, drawing a diagram, writing an equation, using an algorithm to compute, counting, and checking the answer.

As early as the third grade level, the use of strategies becomes apparent in the solution to mathematics word problems. Romberg and Collis (1985) interviewed third graders about their problem solving techniques. Strategies which the students incorporated into their problem solving included; producing a model of the problem (at this grade level the models were not diagrams but were produced with fingers or counting chips), writing open sentences, and using algorithms to compute.

Researchers have found that some of the individual steps commonly found in step by step problem solving plans (e.g. diagramming by Van-Essen & Hamaker, 1990) are effective in increasing students problem solving test scores. However, research investigating the effectiveness of problem solving plans and the potential gender-differentiated effects of using those plans is limited. Some data suggest that the use of step by step plans does represent an effective approach to problem solving (Zambo, 1992) and that a gender-related difference in favor of females exists with the use of those plans for solving routine two-step word problems (Zambo, 1994).

Purpose

The purpose of this study was to further investigate potential gender-differentiated effects of using an explicitly stated problem solving plan. We hoped to provide information about the questions: What are the effects of using a step by step problem solving plan on word problem solving achievement, and does the use of a problem solving plan have gender-related differences?

Procedures

Sample

Six heterogeneous classes of sixth graders, two from each of three elementary schools, from a public school district in the southwestern United States were selected for this study. The students (n=155) were from a mixed SES community and had a large proportion of students with a Hispanic background. There were 77 females and 78 males.

Prior to data collection the teachers completed a survey concerning their instruction on specific problem solving strategies. All of the teachers stated that they used regularly the problem solving strategies incorporated into this study in their classrooms. The teachers felt confident that their students would understand, for example, what it meant to write a number sentence to represent a problem. Interestingly, although all of the teachers reported using problem solving strategies as part of their instruction, they also reported that they taught the individual strategies in isolation, not as parts of a plan for problem solving.

Test Formation

Two forms of a test were developed for data collection. Each test consisted of four word problems. The problems included three two-step word problems used in a previous study of problem solving ability (Zambo, 1994) plus an additional item that had a

geometric orientation. Both tests consisted of a cover page and four additional pages. Each of the four pages contained one of the word problems. One of the tests, the formatted form, included the seven steps of the problem solving plan on each of the pages with space for student work. The other tests, the unformatted form, contained only the word problems.

Data Collection

Three classes of students (n = 73) were administered the formatted test first followed by the unformatted version. The remaining three classes of students (n =82) were administered the unformatted version first followed by the formatted. The teachers reported that no instruction was conducted on problem solving during the interval between the tests and that specific questions about the test items were not addressed until after the second test was completed. Two students, one female and one male, from each of the six classes were identified by their teachers as likely to talk freely to a researcher about their mathematics. These students were interviewed immediately after the second test about the processes they used to solve the problems and their opinions about the problem solving steps supplied in the test. Copies of both the formatted and unformatted tests were available to the students as a reference for this discussion.

Results

For purposes of analyses the students were categorized into one of four groups according to their gender and type of test sequence they received. The four groups were: males receiving the formatted test first followed by the unformatted test, males receiving the unformatted test first followed by the formatted, females receiving the formatted test first followed by the unformatted, and females receiving the formatted test first followed

by the unformatted. Table 1 presents a breakdown of the groups along with mean scores and standard deviations.

Insert Table 1 About Here

The initial analyses examined the effect of type of test (formatted vs. unformatted) for pre test and post test results. An independent t-test of pre test scores found no significant difference between groups who received the formatted version first and those that received the unformatted version first (df=153, t= .599, p = .550). However, for the post test a significant difference was found favoring students who received the formatted post test versus those who received the unformatted post test (df=153, t = 2.30, p = .023). This evidence indicates an effect for type of post test, but we are somewhat cautious because of a possible testing effect.

We also examined the effect of format alone on the basis of subject gender. There was no significant difference (t=1.621, df=71, p = .110) between males and females who received the formatted version of the test, both pre and post. An examination of the same effect for the unformatted tests also revealed a non-significant (t=1.057, df=80, p = .294) difference between males and females on the unformatted test, both pre and post. We conclude that it appears as if there is no difference between males and females regarding the use of unformatted or formatted test forms.

Examination of the effects of student gender by itself indicated no significant difference between males and females on the pre test (t= 1.068, p = .287) or on the post test (t = .493, p = .623). We concluded that gender, without consideration for the pattern of testing did not result in any significant difference.

A second set of analyses involved the examination of the four groups of students utilizing an analysis of variance model for each of the two testing times (pre test and post

test.) The pre test ANOVA did not indicate any significant difference among the four groups (df = 3,151; F = 1.044; p = .375). A similar finding was found for the post test analysis (df = 3, 151; F = 2.337; p = .076). Again, we concluded that examining the effects only on the basis of a pre test or a post test failed to establish any significant differences due to type of item presentation.

The final analysis involved a one-way repeated measures analysis of variance model with the time of testing the repeated factor. The results of this analysis are presented in Table 2. These results do indicate a significant effect of Time-of-test by Group (p = .006). Figure 1 provides a graphic representation of the disordinal effect we found indicating a strong change for female students receiving the formatted version after the unformatted versus the female students who received the formatted version first followed by the unformatted one.

Insert Table 2 About Here

Insert Figure 1 About Here

It appears that for males the order of presentation does not indicate any significant effect, but for females the order is quite important. In fact, female students who received the formatted version first followed by the unformatted actually scored lower on the post test. This was an effect not present for any of the other groups. In all other cases the post test groups out performed the pre test groups with females in the unformatted to formatted group demonstrating a significant change (pre to post) (df = 43, t = 3.618, p = .001).

Transcriptions of the student interviews (N=12) were examined for comments about students' perceived usefulness of the problem solving plans. The males who were tested in the unformatted to formatted sequence (N=4) reported that on the unformatted test they completed the computation and wrote the answer without recording any other information on the test pages. All four commented that the formatted test required more work, more thinking, or a longer amount of time. Three of those four felt that they did better on the formatted tests because the steps of the problem solving plan required them to think more about the problem or that the steps tended to validate each other. The other one of the four held an opposite view, he thought that the steps could be confusing because they caused you to lose the focus of the problem.

Males taking the tests in the formatted to unformatted sequence (N=3) felt that the format was not helpful, that it made the problems harder, or that the steps were confusing. All three said that when they took the second (i.e., formatted test) that they did not use any of the steps for problem solving, they just did the work and wrote the answer.

Females taking the tests in the unformatted to formatted sequence (N=2) reported thinking that the formatted test was more difficult or the steps were confusing. When asked if the steps were of any help for solving the problem, they both said that listing the facts was helpful and one said that drawing the diagram helped. Both reported that on the unformatted test they only computed and answered the questions on the pages provided.

One of the females (N=2) taking the tests in the formatted to unformatted sequence responded that the steps seemed useful but on the second test she just computed and reported answers. The other female said that she liked the formatted test because it allowed her to see what she was doing and that made solving the problems easier than just doing the work (compute and answer). She also said that on second test she tried to remember and duplicate the steps that appeared on the formatted version.

Discussion

The purpose of this study was to investigate potential gender-differentiated effects of using an explicitly stated problem solving plan. We wanted to determine potential effects of using a step by step problem solving plan on word problem solving ability; and if effects were detected, to determine if they were gender differentiated.

It appears that the use of an explicitly stated problem solving plan may have an effect on problem solving. This conclusion is based on the following findings from this study. The students who took the unformatted test first and the formatted test second showed statistically significant improvement in test scores. This result may be confounded by the time of testing which had the anticipated significant effect. It follows that the time of testing would also effect the post test results of the groups who were administered the formatted test first and the unformatted test second. However, a significant gain did not exist for those groups. It seems logical to infer that the time of testing effect for those groups was mediated by the positive effects of the problem solving plan.

It also appears that the effects of the problem solving plan may be gender-differentiated. This conclusion is based on the following two findings from this study. First, the weaker of the two arguments. Some research has reported the existence of gender-related differences in problem solving ability favoring males beginning at the sixth grade level, including routine word problems (Marshall, 1984). Male superiority in problem solving was not apparent in this study. In fact, the highest group score was attained by females on the formatted post test. Possibly, male superiority did not manifest itself because it was balanced by a greater positive influence of the problem solving plan for females than for males (Zambo, 1994).

Second, the interaction effect of Time-of-testing by Group membership was also significant. It should be noted that group membership was determined by both gender

and order of testing. The effects of this interaction are most dramatic in female subjects' scoring related to order of testing. Both groups, female and male, that received the unformatted test first and the formatted test second gained. However, only females made a statistically significant gain. Males who took the formatted test first and the unformatted test second also showed gains. However, females who took the formatted test first and the unformatted test second exhibited a loss. Although there was not a significant main effect for gender, the combination of format and time of testing are interrelated in different ways for females than for males.

Females apparently benefited from exploring problems on their own and then seeing those problems combined with an organized format for analysis and solution. Interview data suggest that when working through the unformatted version, the problems were read and computations were completed. However, the formatted test required more work and a longer amount of time focusing on the problems. This longer interval of time for analysis induced by the presence of the problem solving plan, coupled with some familiarity with the problem had a powerful effect for females but not for males. However, when the females' first experience with the problems included the organization of the problem solving plan, they scored lower on the second test regardless of the test effect. Females did not effectively solve the problems on the second test when the formatting was withheld.

The fact that females seem to benefit from examining problems first and then analyzing them in the context of a problem solving plan, could be used to as a guide to conducting instruction that could help to mediate gender-related differences in problem solving ability. Unfortunately, the design of this study does not allow a direct analysis of the influence of the initial exploration of the problems on the second organized experience. The findings of this study could be used as a guide for designing additional

research investigating the differential effects gender and the order of testing on problem solving ability.

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Table 1

Means and Standard Deviations of Groups for Analysis

	Males Formatted to Unformatted	Males Unformatted to Formatted	Females Formatted to Unformatted	Females Unformatted to Formatted
N	40	38	33	44
Pre Test				
Mean	1.625	1.974	2.091	1.932
Std. Dev.	1.275	1.026	1.156	1.283
Post Test				
Mean	2.075	2.263	1.879	2.545
Std. Dev.	1.185	1.201	.992	1.210

Table 2

Repeated Measures Analysis of Variance

Source	SS	DF	MS	F	p
Between Subjects					
Group	6.960	3	2.320	1.041	.376
Error	336.608	151	2.229		
Within Subjects					
Time	6.238	1	6.230	11.511	.001
Time * Group	6.923	1	2.308	4.259	.006
Error	81.831	151	.0542		

Figure 1

Pre test and Post test Scores by Group